Chapter 4

Size the Kanban

In this chapter we will calculate the kanban quantities for your process. We have proposed two methods for determining the quantities:

1. Calculate the optimal kanban quantity based on your current process data
2. Use the current schedule quantity to set up the kanban

Both methods have decided benefits. Method 1 allows you to optimize the kanban quantities based on the current state of the process. To do this requires accurate data to ensure you get true results. With the data collected in Chapter 3, use the calculation sheet shown in Figure WB 4-1 to summarize and calculate the kanban quantities.

The equations for using this method are shown in Figures WB 4-2 and 4-3. We are also repeating the book examples in this chapter to illustrate and reinforce the use of these equations. Figures WB 4-4 through WB 4-10 show these examples for your review.

If the initial results do not look correct when using method 1, then look at these areas for possible errors:

- Container sizes force added inventory
- Incorrect production data--production requirements, scrap, downtime, and changeovers
- Incorrect buffer assumptions
- Incorrect capacity assumptions

As an alternative, method 2 allows you to avoid the calculations and quickly determine the kanban quantities. However, this method maintains the potential excesses of the current schedule and achieves no calculated inventory reductions. Figure WB 4-11 shows an example of this method.

Regardless of which method you select, when reducing the kanban quantities, use the techniques in Chapter 9 of this *Workbook* to make the reductions. Remember, there is no free lunch, so don't arbitrarily reduce quantities.

When you begin the process of implementing supplier kanbans, use demand data to develop the order quantity and buffer quantity. We have proposed multiplying the standard deviation of each part number's average demand by a confidence interval to calculate a safety buffer. Follow the steps in Chapter 4 of the book to calculate these quantities. Once you have these quantities, conduct a quick stock-out analysis to confirm the appropriateness of the buffers. To perform this analysis:

- Subtract each demand quantity for each part number from the shipment (or average order) plus the calculated buffer
- Repeat this operation for all the demand quantities used to calculate the average shipment and buffer
- Now look at the results to see whether the on-hand quantity (shipment plus buffer) went negative or close to negative

If the on-hand quantity goes negative, then reassess the confidence interval used to calculate the buffer and make changes as appropriate. Figures

WB 4-12 and WB 4-13 repeat the examples from the book on how to calculate the buffer and perform a stock-out analysis for different confidence intervals.

When implementing supplier kanbans, make sure that the supplier agrees to your plans. Once you have agreement on the quantity and delivery schedule, use the information in Chapter 5 to develop a mutually agreeable design for this kanban.

Use the same process proposed for the supplier kanban to size finished goods kanbans. Again, we strongly advise that you do not make a finished goods kanban your first project since learning kanban at the customer's expense may not be the wisest move.

Figure WB 4-1

Schedule Interval: _____

Part Number	Part Name	Interval Production Requirement	Adjusted Production Requirements	Time Required for Production (in minutes)	Leadtime Quantity	Replenishment Quantity	Container Size	Leadtime Container Quantity	Replenishment Container Quantity	Comments

Replenishment Interval = _____

Leadtime Assumptions:

Average Inventory= $\dfrac{\text{Replenishment Interval + Leadtime}}{2}$

Figure WB 4-2

Summary of Kanban Sizing Equations

Adjusted Production Requirments = $\dfrac{\text{Average Production Order}}{\text{(1 - System Scrap)}}$

Adjusted Production Requirments = $\dfrac{\text{Average Production Order}}{\text{(1 - Process Scrap) (1 - Downstream Scrap)}}$

Available Time = Total Time in a Shift
- (Planned and Unplanned Downtime)

Available Time (Continuous Processes) = Total Time in a Shift
- (Time for Planned Maintenance, Cleaning, and Breakdowns)

Time Required for Production = **Sum** (Adjusted Production Requirements x Cycle Time Per Part)

Time Available for Changeovers = Total Available Time
- Time Required for Production

Replenishment Interval = $\dfrac{\text{Total Time } \textit{Required} \text{ for Changeovers}}{\text{Total Time } \textit{Available} \text{ for Changeovers}}$

Container = (Buffer Quantity + Replenishment Interval Quantity)

Figure WB 4-3

Schedule Interval: _____

Part Number	Part Name	Interval Production Requirement	Adjusted Production Requirements	Time Required for Production (in minutes)	Leadtime Quantity	Replenishment Quantity	Container Size	Buffer Container Quantity	Replenishment Container Quantity	Comments

Multiply the interval production requirements by the scrap levels using the equations in Figures 4-2 or 4-3 to calculate the adjusted Production Requirements

Adjusted Production Requirements x Cycle Time per Part

Buffer Quantity / Container Size

Adjusted Production Requirements x Buffer

Adjusted Production Requirements x Replenishment Interval

Replenishment Quantity / Container Size

Replenishment Interval = _____

Buffer Assumptions:

$$\text{Average Inventory} = \frac{\text{Replenishment Interval} + \text{Buffer}}{2}$$

Figure WB 4-4

Example 1: In Chapter 3 we outlined the details of a process which produces injected molded plastic rings. Figure 3-5 summarizes the data for this example.
-Use this data to calculate the time available for changeovers

Schedule Interval: Daily

Part Number	Part Name	Interval Production Requirement	Adjusted Production Requirements	Time Required for Production (in minutes)	Buffer	Container Size	Replenishment Container Quantity	Buffer Container Quantity	Comments
A	Red Carnival Ring	500	515	129					
B	Blue Carnival Ring	800	825	200					

$\frac{500}{(1-.03)}$

$\frac{800}{(1-.03)}$

Available Time (using Equation 4.5):

Total Time in a Shift		480 minutes
Planned Downtime	-	65 minutes
Unplanned Downtime	-	60 minutes
		355

Interval Run Time

Converting to Minutes :

A	515 parts * 15 seconds/part	=7725 seconds	=	$\frac{7725}{60 \text{ secs/min}}$ = 129 minutes
B	825 parts * 15 seconds/part	=12375 seconds	=	$\frac{12375}{60 \text{ secs/min}}$ = 207 minutes

Finally: **Total Time Available for Changeover = 355 - (129 + 207)**
= 19 minutes

Figure WB 4-5

Example 1 Replenishment Interval Calculation

Time Required for Changeovers = 30 Minutes

Time Available for Changeover = 19 Minutes

Finally:

$$\text{Replenishment Interval} = \frac{30 \text{ minutes}}{19 \text{ minutes}}$$

$$= \mathbf{1.58}$$

Figure WB 4-6

Schedule Interval: Daily

Part Number	Part Name	Interval Production Requirement	Adjusted Production Requirements	Time Required for Production (in minutes)	Buffer	Replenishment Quantity	Container Size	Buffer Container Quantity	Replenishment Container Quantity	Comments
A	Red Carnival Ring	500	515	129	515	1030	500	2	3	
B	Blue Carnival Ring	800	825	200	800	1650	50	16	33	

1 x 515

2 x 515

515 / 500

1030 / 500

Replenishment Interval = **1.58 or 2**

Average Inventory= (Replenishment Interval + Buffer) / 2

= (2+ 1) / 2 = **1.5 Days**

Buffer Assumptions:

Safety Stock	1
Advertised Delivery Commitment	0
Process	0
Total	**1**

Since we have simple process with a quick changeover and a reliable supplier, we will hold one day of buffer inventory for safety stock and customer orders.
--We will not consider the 15 minute cooling time as needing buffer.
--Note we gain some buffer by scaling up our replenishment interval to 2 days from 1.58.

Figure WB 4-7

Schedule Interval: Daily

Part Number	Part Name	Interval Production Requirement	Adjusted Production Requirements	Time Required for Production (in minutes)	Buffer	Replenishment Quantity	Container Size	Buffer Container Quantity	Replenishment Container Quantity	Comments
A	Red Carnival Ring	500	515	129	515	1030	***50***	***11***	***21***	New container quantity with resized containers
B	Blue Carnival Ring	800	825	200	800	1650	50	16	33	

515 / 50

1030 / 50

Replenishment Interval = **1.58 or 2**

$$\text{Average Inventory} = \frac{\text{Replenishment Interval + Buffer}}{2}$$

$$= (2+ 1) / 2 = \textbf{1.5 Days}$$

Buffer Assumptions:

Safety Stock	1
Advertised Delivery Commitment	0
Process	0
Total	**1**

Since we have simple process with a quick changeover and a reliable supplier, we will hold one day of buffer inventory for safety stock and customer orders.
--We will not consider the 15 minute cooling time as needing buffer.
--Note we gain some buffer by scaling up our replenishment interval to 2 days from 1.58.

Figure WB 4-8

Example 2: In Chapter 3 we outlined the particulars of a plastic extrusion process which extruded 10 different profiles. Figure 3-13 summarizes the data for this example.
-Use this data to calculate the time available for changeovers

Schedule Interval: Daily

Part Number	Part Name	Interval Production Requirement	Adjusted Production Requirements	Time Required for Production (in minutes)	Buffer	Container Size	Replenishment Container Quantity	Buffer Container Quantity	Comments
3502		500	531	17					
3503		750	806	31					
3504		350	388	31					
3505		250	269	4					
3506		500	537	9					
3507		500	531	17					
3508		1200	1237	47					
3509		1000	1074	98					
3510		900	932	27					
3511		100	107	3					
			Total	284					

Where **Time Required for Production**
= Production Rate
x Adjusted Production Requirement

ex. Part 3502 = 1.97 seconds/part
x 531 parts
= 1046 seconds
= 1046/60
= 17 minutes

$$\frac{100}{(1-.05)(1-.02)}$$

Available Time (using Equation 4.5):

Total Time in a Shift		480	Minutes
Planned Downtime	-	0	Minutes
Unplanned Downtime	-	72	Minutes
		408	

Total time Available for Changeover:

Available Time		408
Time Required for Production	-	284
		124

Figure WB 4-9

Example 2 Replenishment Interval Calculation

Time Required for Changeovers = 290 minutes [From Figure 3-13]

Time Available for Changeover = 124 minutes [From Figure 4-10]

Finally:

$$\textbf{Replenishment Interval} = \frac{290 \text{ minutes}}{124 \text{ minutes}}$$

$$= \mathbf{2.34}$$

Figure WB 4-10

Schedule Interval: _____

Part Number	Part Name	Interval Production Requirement	Adjusted Production Requirements	Time Required for Production (in minutes)	Buffer	Replenishment Quantity	Container Size	Buffer Container Quantity	Replenishment Container Quantity	Comments
3502		500	531	17	1063	1594	100	11	16	
3503		750	806	31	1611	2417	100	16	24	
3504		350	388	31	776	1164	100	8	12	
3505		250	269	4	537	806	100	5	8	
3506		500	537	9	1074	1611	100	11	16	
3507		500	531	17	1063	1594	100	11	16	
3508		1200	1237	47	2474	3711	100	25	37	
3509		1000	1074	98	2148	3222	100	21	32	
3510		900	932	27	1865	2797	100	19	28	
3511		100	107	3	215	322	100	2	3	

1594 / 100

1063 / 100

2 x 531

3 x 531

Replenishment Interval = **2.34 or 3**

Average Inventory= (Replenishment Interval + Buffer) / 2

= (3 + 2) / 2 = **2.5 Days**

Buffer Assumptions:

Saftey Stock	**1**
Process	**0**
Supplier	**1**
Total	**2**

We have more complicated process due to all the part numbers but have a quick changeover and low downtime, we will hold one day of buffer inventory for safety stock and customer orders.
--We have no process curing requirements.
--We added a day to finished products because we have an unreliable supplier.
--Note that we gain some buffer by scaling up our replenishment interval to 3 days from 2.34.

Figure WB 4-11

Method 2 Example

Based on your years of experience you decide to set up the kanban to run everything once per week. Using the same data as in Example 2, you figure your adjusted production requirements and determine the number of containers in your kanban. You decide to maintain a buffer of 2 days to protect yourself from stock outs and as a safety factor.

Schedule Interval: _____

Part Number	Part Name	Interval Production Requirement	Adjusted Production Requirements	Time Required for Production (in minutes)	Buffer	Replenishment Quantity	Container Size	Buffer Container Quantity	Replenishment Container Quantity	Comments
3502		500	531	17	1063	2657	100	11	27	
3503		750	806	31	1611	4028	100	16	40	
3504		350	388	31	776	1939	100	8	19	
3505		250	269	4	537	1343	100	5	13	
3506		500	537	9	1074	2685	100	11	27	
3507		500	531	17	1063	2657	100	11	27	
3508		1200	1237	47	2474	6184	100	25	62	
3509		1000	1074	98	2148	5371	100	21	54	
3510		900	932	27	1865	4662	100	19	47	
3511		100	107	3	215	537	100	2	5	

Required Pieces for 5 days:

531	x 5	=	2657
806	x 5	=	4028
388	x 5	=	1939
269	x 5	=	1343
537	x 5	=	2685
531	x 5	=	2657
1237	x 5	=	6184
1074	x 5	=	5371
932	x 5	=	4662
107	x 5	=	537

Required Pieces for 2 day Buffer:

531	x 2	=	1063
806	x 2	=	1611
388	x 2	=	776
269	x 2	=	537
537	x 2	=	1074
531	x 2	=	1063
1237	x 2	=	2474
1074	x 2	=	2148
932	x 2	=	1865
107	x 2	=	215

Figure WB 4-12

Calculating a Buffer Where Demand Variation Exist

Product	wk 1	wk 2	wk 3	wk 4	wk 5	wk 6	wk 7	wk 8	wk 9	wk 10	wk 11	wk 12	Average Usage	Standard Deviation
A	300	250	275	350	325	310	305	285	295	285	305	300	299	25
B	700	740	800	735	750	790	785	800	725	745	775	750	758	32
C	500	560	600	625	550	575	525	565	610	635	550	580	573	40
D	900	935	950	890	880	975	940	935	980	925	955	960	935	32
E	775	800	795	785	805	840	835	810	820	790	825	800	807	20

Use the 12 week demand to calculate the average and standard deviation for this example.

Product	Average Usage	Standard Deviation	Leadtime Buffer Based on Confidence Intervals				
			0.99	0.975	0.95	0.925	0.9
A	299	25	58	49	41	36	32
B	758	32	74	62	52	46	41
C	573	40	93	78	66	58	51
D	935	32	74	63	53	46	41
E	807	20	47	39	33	29	26

Basic Calculation:

=0.9 Confidence Interval
x Standard Deviation for Part A
=1.282 x 25
=32

Figure WB 4-13

Stock Out Analysis For Various Confidence Levels

Stockout Analysis with 99% Confidence Interval

Product	wk 1	wk 2	wk 3	wk 4	wk 5	wk 6	wk 7	wk 8	wk 9	wk 10	wk 11	wk 12
A	57	107	82	7	32	47	52	72	62	72	52	57
B	132	92	32	97	82	42	47	32	107	87	57	82
C	166	106	66	41	116	91	141	101	56	31	116	86
D	110	75	60	120	130	35	70	75	30	85	55	50
E	78	53	58	68	48	13	18	43	33	63	28	53

(299 + 49) - 300

(573 + 78) - 610

Stockout Analysis with 97.5% Confidence Interval

Product	wk 1	wk 2	wk 3	wk 4	wk 5	wk 6	wk 7	wk 8	wk 9	wk 10	wk 11	wk 12
A	48	98	73	***-2***	23	38	43	63	53	63	43	48
B	120	80	20	85	70	30	35	20	95	75	45	70
C	151	91	51	26	101	76	126	86	41	16	101	71
D	98	63	48	108	118	23	58	63	18	73	43	38
E	71	46	51	61	41	6	11	36	26	56	21	46

Stockout Analysis with 95% Confidence Interval

Product	wk 1	wk 2	wk 3	wk 4	wk 5	wk 6	wk 7	wk 8	wk 9	wk 10	wk 11	wk 12
A	40	90	65	***-10***	15	30	35	55	45	55	35	40
B	110	70	10	75	60	20	25	10	85	65	35	60
C	139	79	39	14	89	64	114	74	29	4	89	59
D	88	53	38	98	108	13	48	53	8	63	33	28
E	65	40	45	55	35	0	5	30	20	50	15	40

Stockout Analysis with 92.5% Confidence Interval

Product	wk 1	wk 2	wk 3	wk 4	wk 5	wk 6	wk 7	wk 8	wk 9	wk 10	wk 11	wk 12
A	35	85	60	***-15***	10	25	30	50	40	50	30	35
B	104	64	4	69	54	14	19	4	79	59	29	54
C	131	71	31	6	81	56	106	66	21	***-4***	81	51
D	82	47	32	92	102	7	42	47	2	57	27	22
E	61	36	41	51	31	***-4***	1	26	16	46	11	36

Stockout Analysis with 90% Confidence Interval

Product	wk 1	wk 2	wk 3	wk 4	wk 5	wk 6	wk 7	wk 8	wk 9	wk 10	wk 11	wk 12
A	31	81	56	***-19***	6	21	26	46	36	46	26	31
B	99	59	***-1***	64	49	9	14	***-1***	74	54	24	49